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UNDERSTANDING OF CONCEPT AND ABILITY OF PROBLEM-SOLVING AT STUDENTS OF MATHEMATICS EDUCATION DEPARTMENT UIN SUSKA RIAU BASED-ON COGNITIVE LOAD THEORY

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Abstract

Learning is continual process in constructing own knowledge of each individual. It is on the right track that the learning becomes pleasing thing, interesting and haves a clear purpose. But, there are still assumptions that the learning get hardly troubles, especially in Mathematics study. There are things that make the study doesn't get its essential (purpose). The cognitive load theory discusses about the load felt by someone in learning related to the memory system to reach expected purpose of learning. The purpose of learning is closely related to the understanding of concept obtained from learning process and utilized to solve problem happened as according to available concept. Through the cognitive load theory, the students construct again their knowledge to finalize mathematics problem. The research findings showed that the understanding of concept and ability to solve Mathematics problems at students in Mathematics Education Department UIN Suska Riau by applying the Cognitive Load Theory improved significantly from unfavourable criterion to be a better one.

Keyword: *The cognitive Load Theory, Concept Understanding, Problem-Solving*

Introduction

Background

Learning can expand someone's knowledge in getting life experiences as a process that is interconnected each other. Learning during the time will make man can think realistic, systematic, and open to change. Learning concept during the time must be owned by students in study, especially mathematics study. Study of mathematics need to be well-designed so that study to become having a meaning for student in construct their own knowledge in learning. A study of course does not quit from various problems, especially in the process of learning. This thing also happened to the students of mathematics education going through lecturing of real analysis, most of their concept understanding are weak in finalizing mathematics problems.

The difficulty in mathematics learning experienced by student to finalize problem for example was caused by the existence of cognitive load with the indicators of un-systematic and uncontinuous subject explaination, presentation of matter in the form of picture or graph sketch that is not satisfactory and graceless, and also the study that doesn't give the opportunity of student to explore ability, knowledge and student understanding. Cognitive Load Theory or CLT identifies that learning is annoyed when full scale of processing clauses exceeds limited capacities from man's job memory. The cognitive load theory (Sweller, 2009) is a framework based on research to investigate learning as function of man memory and processing. This thing gives guidance which in such a manner to assist in presentation of information causing pushs cognitive activity in optimal learning of intellectual performance. The cognitive load theory especially relates to two areas : man's memory structure (cognitive architecture) and how information is processed (cognitive load).

Man's cognitive architecture is widely confessed consists of three memory systems that is sensoric memory, activity memory (or short-term) and long-term memory (or permanent). When considering cognitive processing, the things happened in activity memory is that the number of individual processings must allocate a duty so-called as amounts of 'Cognitive load'. The consideration on how cognitive load influences learning is one of basic objective of cognitive load theory. Three types of cognitive loads (Clark et al, 2006) :

a. Intrinsic cognitive load – mind activity that is closely forced by content demand. This thing is especially determined by instructional purpose, and knowledge and skill related to instructional purpose.
b. Germane Cognitive load (or relevant) – mind activity applied by instructional activity that is profitable for instructional purpose through acquisition of scheme. This is relevant load applied with teaching method leading to a better learning result. This thing can be considered to be mind effort applied to form scheme and active to integrate new information with prior knowledge. This is difference between students copies information from textbook (low tight load), or designs and executes experiments (high tight load).
c. Extraneous Cognitive Load (or irrelevant) – mind activity that is not relevant with the purpose to study, applied by instructional desainer, in structure and presentation of information. Mussy handwriting is an example of extra load, with many mind efforts required to elaborate meaning, without useful purpose.

The difficulty of student learning can be overcome with effective study. This thing is reachable with managing intrinsic cognitive load, lessens extraneous cognitive load and increases germane cognitive load (Kalyuga, 2009), all in limited activity memory processes. So lecturer must develop strategy which can create effective study. To execute study which based on the Cognitive load theory, strategy used in study of real analysis of real number subject is guided invention strategy.

Guided Invention is a study which in its implementation teacher/lecturer allows their students to think themselves until they can find expected general principle with tuition and guide from teachers/lecturers. Guided Invention as useful teaching strategy for study of mathematics has benefits and insuffiency. According

To Widdiharto (2004), the benefits and lacking of guided invention method are as follows :

1. **Benefits**
   a) Student can participate actively in learning activity.
   b) To develop and also inculcate inquiry talent.
   c) To support the ability of student's problem solving.
   d) Subjects studied can reach high ability level and durable since student involved in process to find it.
2. **Insuffiency**
   a) For certain subjects, time used is longer.
   b) Not all students can follow lesson in this way. In field, some students are still accustomed and easy to understand with discourse method.
   c) Not all topics is compatible to be submitted with this method. Generally topics relating to principle can be developed with guided invention method (p. 6).

From the excess of guided invention strategy, one of them is to be able to increase the ability to solve problem. So, during study of real analysis will be applied guided invention strategy based on the cognitive load theory to increase the understanding ability of concept affecting at the better ability to solve problem.

Theoretical Reviews

1. The Cognitive Load Theory

Cognitive Load Theory (*CLT*) is desain instructional design theory with the purpose to assist instructional designer to minimize the load caused by bad design of learning subject. CLT uses approach of information process to cognitive, that involves working memory and long term memory (Errey et al, 2006). This gives a particular guide to assist in presenting information that support cognitive activity in learning to optimize intellectual performance (Sweller, van Merienboer & Paas). Cognitive Load Theory relates to two fields of man memory structure and how the information is processed *(*Cognitive Load*)*. Cognitive load theory deals with two areas, namely the structure of human memory and how information is processed (cognitive load). Structure of human memory consists of three memory systems are sensory memory (sensory memory), the (short term) working memory (short-term memory or working memory), and the long term memory (long term memory).

a. Sensory memory (sensory memory) refers to the ability of sensory information to be preserved after the physical representation has been stopped. It can be considered a retention shortly after an individual is focused on the visual and audio information. Sensory memory has a significant capacity but very short retention time.
b. The (short term) working memory (short-term memory or working memory) refers to the organization and processing of sensory information by the brain. This limited both in storage capacity and retention time. Working memory can be equated with consciousness, the conscious and the only people who are able to monitor, the contents of working memory (Sweller, van Merienboer & Paas). Miller was one of the first to make explicit the limits of working memory with

rule 'seven plus or minus two' - working memory and processing is capable of holding a maximum of about seven 'chunks' of information at a time (Errey et al, 2006). Working memory intellectual activities associated with thinking and processing information. However, working memory is limited in capacity and duration.

c. The long term memory (long term memory), in contrast to working memory, large storage capacity, and represent almost permanently storing information in humans. But man, is not directly aware of the long-term memory. Instead, awareness of the content and function of long-term memory is filtered through the working memory. Long term memory center of knowledge and skills.

Information processing begins when the information in the form of visual and audio information received by sensory memory, then forwarded to the working memory. Furthermore, working memory manage the received information to be stored into long-term memory. The screening process information in working memory takes place in a very fast time. Information stored in long term memory can be recalled by the working memory.

When considering cognitive processing in activity memory, it should be allocated the number of processings for a duty so-called as amounts 'cognitive burden'. The consideration of how cognitive load influences learning is one of core purpose of the cognitive burden theory. Three types of cognitive load (Clark et al, 2006):

1) Intrinsic Cognitive Load

Intrinsic burden is mind working forced by content demand. This thing is especially determined by instructional purpose, and knowledge and skill related to instructional purpose. Management indicator of intrinsic cognitive load presented in Table 3.1.

Table 1 Processing Indicator of Intrinsic Cognitive Load

No.	Intrinsic Cognitive Load	To Manage Intrinsic Cognitive Load
1.	Level of Information Complexity or subjects studied	To manage information or complex subject to be simpler with learning by using module, worksheet, learning media.
2.	Learning irrelevant with learning purpose, knowledge and student's skills	Learning design based on existing curicullum with priority on learning purpose, knowledge and student's skills

2) Germane (or Relevant) Cognitive Load

Germane Cognitive Load is mind working applied by activity of instructional activity which is profitable to instructional purpose through scheme acquisition. This thing can be considered to be mind effort applied to form active scheme to integrate new information with prior knowledge. Improvement indicator of germane cognitive load presented in Table 3.2.

Table 2 Improvement Indicator of Germane Cognitive Load

No.	Germane Cognitive Load	To Improve Germane Cognitive Load
1.	Students feel strange with information or subjects presented so they are not interesting.	To review prior knowledge related to information or subjects presented
2.	Learning doesn't give opportunity for students to explore student's ability, knowledge and understanding	Learning is designed to explore student's ability, knowledge and understanding through discussion that give opportunity to express idea and execute self trial by media assistance
3.	Information or subjects presented can not be well understood	Provide reinforcement and help make inferences from the material being studied

3) Extraneous (or Irrelevant) Cognitive Load

Extraneous Cognitive Load is mind working which is not relevant with learning purpose, applied by instructional designer, in structure and information presentation. Hence, this wastes limited activity memory resource, reduces usable capacity used for relevant load. Indicator to reduce extraneous cognitive load is presented in Table 3.3.

Table 3 Indicator to Reduce Extraneous Cognitive Load

No.	Extraneous Cognitive Load	To reduce Extraneous Cognitive Load
1.	Expression of unsystematic or unconsecutively information or subjects.	Learning is designed to express unsystematic or unconsecutively information or subjects with media assistance
2.	Less teacher's guidance to help students in understanding information or subjects in learning	To assist students individually and group in understanding information or subjects in learning as well as to solve exercises
3.	Interaction between students is less or student's interaction can disturb other students	Learning is designed to present high interaction between students with questions-answers, discussion, as well as do guidance individually or in group
4.	The presentation of information or subjects by pictures or graphs is not clear	Learning by using media
5.	Information or subjects of pictures or graphs is not interesting for students because they don't try it yet.	To give opportunity for students to use media to make pictures or graphs

Therefore, effective teaching is layed in optimization of cognitive load in limited activity memory capacity from students. If the limit of capacity excess load (cognitive overload), hence performance become lower (Sweller, 2009). The principle of cognitive load theory is effective study that is reachable with managing intrinsic cognitive load, lessens extraneous cognitive load and increases germane cognitive load (Kalyuga, 2009), all are in the process of limited activity memories.

2. Concept Understanding

One of some ideas and opinion received in education community of mathematics is the idea that student must comprehend mathematics. The knowledgeable is interpreted from the word "*understanding*". Understanding is interpreted as meaning absorption of a studied subject material. To comprehend an object exhaustively, someone must know:

a. The object itself
b. The relationship with other similar object
c. The relationship with other object of which is not similar, and
d. The relationship with object in other theory.

The degree of understanding is determined by the strength of interrelationships from an idea, procedure or mathematics fact is wholly comprehended, if the things constructs a network with strong and a lot of interrelationship. This real philosophic knowledge is a very important thing and interesting to investigate. In knowledge mathematics which must be comprehended consists of two things, that is:

a. Conceptual knowledge that is based to the connectivity network so that each other can connect from cutting diskrit of an information.
b. Procedural knowledge that is based to a number of stages from activity done which including order and algorithm

3. Problem-Solving

In learning with problem-solving approach, activity emphasis is addressed at what must be solved and how to solve the problems systematically and logical. So student is expected able to apply operation to think high level enabling to solve its problem.

Therefore, trouble-shooting steps applied in this research is as told by Polya. The steps are as follows:

a) To comprehend problem. In this phase, student is guided to comprehend a problem clearly that they face, obtains summary completely from what was known and what is asked and enquires where there are unclear things in the problem
b) To compile plan/execute solution. In this phase, student is guided to identify and able to change problem to be clearer problem, and prepares various strategies or method used at next phases. Students at this phase are greatly influenced by their experiences in finalizing problem, generally the more various their experiences are, there is a tendency that the student is more creative in compiling/planning

in resolving a problem. In learning process, student can plan for solving if the student can make the solution steps in systematic way.

c) To execute plan/calculation. If solving plan had been compiled, then the problem is solved as according to plan that is most precisely assumed. In finalizing problem, student is given an opportunity to apply other alternative in solving problem or the way of finalizing problem with more than one alternative answer
d) To re-examines. In this phase, student is guided to investigate whether the process and the result have been done carefully and correctly. By this way, hence the possible mistakes on three prior phases will be corrected again, so that student can finalize problem correctly.

Research Methodology

This research is quasi-experimental study to test the hypothesis, about whether or not there is a significant difference of the variables studied. The population in this research is the 5th semester students of academic year 2011/2012. Half of all students 5 which consists of 4 parallel classes, two classes were randomly taken as the sample for the research, which is being experimental class that is half of the control class 5C and 5A semesters.

Experimental design used in this research form the Randomized Preetest-posttest control group design or design pretest-posttest control group drawn randomly involving two groups: an experimental group and a control group. The experimental group received study treatment with cognitive load theory, while the control group received lessons in the normal way. Both groups were given a pretest and posttest. For more details the research design is described in the following table:

Table Design of Research

Group	Taking	Pretest	Treatment	Posttest
experiment	A	O	X	O
control	A	O		O

A = a random sample / random
O = pretest and posttest
X = treatment with learning based on cognitive load theory

The steps be taken in making 36 students sampled in the research for each class are as follows:

1. Based on the results of the value of the course Fundamentals of Mathematics, Linear Algebra in the previous semester, students are grouped into three groups, ie groups of high, medium, and low.
2. From the above groupings, each category is divided into two groups based on gender.
3. The final step is to take random 6 male students and 6 female students with high ability categories, 6 male students and 6 female students with moderate ability categories, 6 male students and 6 female students with low proficiency category.

The data in this study were obtained by using three kinds of research instruments, namely: test reasoning and understanding mathematical description of shape, attitude scales with Likert scale models. Shaped test descriptions used in this

study to obtain quantitative data that understanding of concepts and problem solving skills after participating in learning mathematics. Comprehension and reasoning test is based on the formulation of specific learning objectives or learning indicators as outlined in the test grating and the test is given to students before and after the implementation of learning in the experimental group and the control group . Attitude scale with Likert scale models are used to determine student attitudes towards learning based on cognitive load theory.

Techniques of data analysis performed in this study are as follows:

a. Determine the average gain score and standard deviation on the pretest and posttest for data comprehension and reasoning test in the experimental group and the control group.
b. Normality test to determine the normality of the data from each group.
c. To test the homogeneity of variance between the control group and the experimental group, which is intended to determine the state of variance both groups , the same or different.
d. To test the difference of two on average. This test is used to test the difference between two average the data, the data in this case between the experimental group and control group data. Hypotheses to be tested are :
    1) Improved understanding and reasoning abilities to the understanding of concepts and mathematical problem-solving skills of students who received learning based on cognitive load theory better than students who received regular lessons.
    2) There was an interaction between learning based on cognitive load theory with gender on increasing understanding and reasoning abilities to the understanding of concepts and mathematical problem-solving skills of students.
    3) There was an interaction between learning based on cognitive load theory to the category of student ability on increasing understanding and reasoning abilities to the understanding of concepts and mathematical problem-solving skills of students.

Result of Research

From the test result of above hypothesis, it was obtained the result that both alternative hypothesises submitted were acceptable significantly. Hereunder, this will be explained each acceptance of both hypothesis:

Firstly : examination of first hypothesis concluded that there was a difference of conceptual understanding between students learning based on the Cognitive load theory with student using conventional approach with value of t calculation = 3,36 > t table = 2,02 at trust level of 95 %. While from result of test, the average value of student's concept understanding in experiment class was higher than mean in control class. This value gave understanding that existence of influence from giving of action in this case was study of real analysis based on the Cognitive load theory to understanding of student concept.

Second: examination of second hypothesis concluded that there was ability difference of trouble-shooting between students who learnt based on the Cognitive

load theory with student using conventional approach with value of t calculate = 2,18 > t table = 2,02 at trust level of 95 %. While from result of test, average of ability value of trouble-shooting in experiment class was higher than mean in control class. This value gave understanding that existence of influence from giving of action is study of real analysis based on the Cognitive load theory toward the ability of trouble-shooting by students. Since there were differences of average test between both research samples, where mean of experiment class is above 70, with 'good' category, while in control class, mean was still under 70. From above explanation, knowable that study of real analysis which based on the Cognitive load theory could give positive influence toward the understanding of concept and ability of problem-solving at students.

Conclusion and Suggestion

There was positive influence of the conceptual understanding and ability of problem-solving at students toward learning based on the Cognitive load theory where the average scores in experiment class was above control class that was >70. In this research, the study emphasized on the learning activity of student centre with managing Intrinsic Cognitive Load (To manage information or complex subjects became more simple in learning with LKS (worksheet) and summary from source of reference), by lessening Extraneous Cognitive Load (To guide student individually and group in comprehending information or subjects in study and also in finalizing exercises correlated with real number by more discussion and question and answer) and increased Germane Cognitive Load (To carry out aperception by correlating prior knowledge relating to information or real number subjects presented, to give an opportunity to the student to submit idea and to execute their own attempts with the help of pictures/media, to give reinforcement and to assist in producing conclusion from real number subjects).

Suggestion submitted before executing the study which based on at the Cognitive Load Theory that made positive effect to conceptual understanding and ability of trouble-shooting need to be prepared by lecturer is being creative in designing situation/problem which will be solved by student. For better study, the student is given duty to be expostulated with small group consisted of one or two people only, this avoids crowded class situation because group discussion that is too big.

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